Foreword to the Special Issue on Paving the Way for the Future of Urban Remote Sensing

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THE RAPID urban growth and the multiple changes of the urban environments pose unique challenges to cities across the globe. Due to the high rates of urbanization on our planet, it is often argued that the future of humanity will be decided in cities. This means that innovative solutions are required to develop new ideas and concepts to make cities resilient, sustainable, inclusive, and prosperous at the same time. To ensure sustainable urban development, however, the basis is first of all knowledge about our cities. Efficient monitoring is required of various aspects of the evolution of urban form, for assessing and forecasting interactions with other environments and resources, and for the development of applied solutions to the various urban challenges in terms of planning, safety, health, infrastructure, service provision, etc. Remote sensing is the tool to gain geoinformation in a consistent and systematic way, basically anywhere across the globe, and with it to fill in still existing large data gaps on cities on our planet. With the ever-growing number and types of sensors, recent advances in technologies (e.g., geospatial remote sensing, unmanned aerial vehicles, autonomous vehicles, hand-held devices), and large volumes of data available from volunteered geographical information, Internet of Things based systems, etc., urban sensing and modeling remains a thrilling field of research with a more promising outlook for developing practical solutions for such continuously evolving ecosystems.

The urban remote sensing community is a dynamic and interdisciplinary network working on various aspects of urban analysis. This network has its focal point at the biennial event Joint Urban Remote Sensing Event (JURSE). JURSE is a forum of excellence where researchers, practitioners, and students present, share, and discuss their latest findings and results. The 2019 edition took place in Vannes, France, from May 22–24th, 2019 (http://jurse2019.org/), featuring keynotes from Xiaoxiang Zhu, Karen Seto, Florence Tupin, and Philippe Clergeau, numerous methodological and thematic special sessions, pre-event technical tutorials and hackathon, a contest on urban climatology, some paper awards, and finally an exciting 3 minutes thesis competition. JURSE 2019 introduced innovative methodologies and technological resources recently employed to investigate the manifold aspects of the urban environment through orbital and airborne remote sensing data. At the moment, the rapid innovations toward artificial intelligence seem to create a new paradigm. These methodological approaches are indeed very powerful in image analysis and in linking heterogeneous datasets. However, associated algorithms only give us more geoinformation but still fail in providing easily accessible, robust, and reliable outputs of guiding decisions of urban actors such as urban planners. During these three rich days of exchanges, we observed this increasing importance of topics related to the possibilities of recent neural networks approaches, but we also noticed an important contribution of new sensors (UAV, LiDAR, etc.) to provide a finer understanding of urban environments. In addition to these methodological aspects, we noticed particular focuses on the urban thermal patterns and the detection of complex morphologies, associated with poverty and slums in the Global South in particular.

This Special Issue consists of six articles covering a range of topics providing a glimpse of the state of the art in the fields of urban mapping and analysis using data from diverse sources. We received 21 submissions, and we involved an international pool of more than 30 experts in the review process. Authors had to deal also with the challenges to work on publications during COVID-19 lockdowns, and we are grateful for their contributions under difficult circumstances.

The articles cover a wide range of thematic areas, from classification and detection of urban objects (e.g., buildings, vehicles) and uncertainty-aware geovisualization of urban scenes to urban climate monitoring and poverty mapping. These articles use a large range of sensors and data (time series of satellite images, optical and SAR data, mobile mapping systems, and crowdsourcing) and show both the multiplicity of opportunities left to researchers to foster information extraction from the most adequate sources and the challenges lying in data fusion and multivariate data analysis. These articles highlight the complexity of urban space by analyzing cities in terms of environmental, socio-economic dynamics, vertical and horizontal states, and fluxes of transport systems. Methods range from classical human image interpretation (at urban scale the most common method to provide exact base data) to latest advances in machine learning and more specifically deep learning. The works gathered in this Special Issue link scientific innovations with societal relevance by discussing the application potentials and the gaps remote sensing data fill to guide urban decision making and evidence-based policy making.

The accuracy of supervised classifiers, including those based on deep learning, strongly relies on the quality of the training data. Such data are usually generated through a manual visual image interpretation, a process sensitive to the intrinsic uncertainty of the cognitive perception. This is addressed by Kraff *et al.* in the article "Uncertainties of human perception in visual image interpretation in complex urban environments," where the authors study the consistency among intra- and interusers mapping inputs to extract built-up areas. In their article "Satellite-based mapping of urban poverty with transfer-learned slum morphologies," Stark *et al.* embed the Xception neural network

Digital Object Identifier 10.1109/JSTARS.2020.3046096

in a fully convolutional architecture in order to perform slum mapping and poverty estimation at a large scale. They consider a transfer-learning scenario to deal with the great variability of slums observed in America, Africa, and Asia. Urban climatology is addressed in two articles. The article by Vulova *et al.* deals with the daily prediction of nocturnal temperatures in "Summer nights in Berlin, Germany: Modeling air temperature spatially with remote sensing, crowdsourced weather data, and machine learning." Their study shows how crowdsourced data (i.e., citizen weather stations) can be used together with EO public data, such as Landsat imagery and Urban Atlas, in order to train supervised prediction models able to reach a degree-level precision. In their article "Monitoring seasonal and diurnal surface urban heat islands variations using Landsat-scale data in Hefei, China, 2000–2017," Lu *et al.* aim to a better understanding of the surface urban heat island with a focus on their diurnal and seasonal variations, and a study of their relationships with landscape patterns. MODIS and Landsat data are used to generate land surface temperature time series and to assess the roles played by the different land cover classes (impervious, water, vegetation), highlighting the specific mitigation effect of vegetation. In the article "Vehicle tracking and speed estimation from roadside lidar," Zhang *et al.* propose to analyze 3-D point clouds acquired from the panoramic LiDAR sensors in order to detect vehicles in urban scenes, and then to track them through unscented Kalman filter and joint probabilistic data association filter followed by a tracking refinement module. By doing so, they are then able to estimate vehicle speed with high accuracy. Finally, in the article "Leveraging ALOS-2 PALSAR-2 for mapping built-up areas and assessing their vertical component," Corbane *et al.* focus on the characterization of built-up areas and assess both horizontal and vertical extents using PALSAR-2 radar data. The method relies on symbolic machine learning and benefits the different orientation angles brought by the ascending and descending sensor orbits, achieving high accuracies on Chicago and Tokyo cities.

Generally speaking, the rise of artificial intelligence seems to create a new paradigm. And yes, these methodological approaches are very powerful in image analysis and in linking heterogeneous datasets. But, and we should keep this in mind despite all the technical euphoria, these algorithms require large and well-designed repositories of training data, have unresolved issues such as related to biases and transferability, and only give us more geoinformation. They do not give us any clear instructions for action. The ordered world of bits and bytes is undercomplex compared to our world and especially to the complexity of our urban environment. Against this background, the JURSE conference series tries to do exactly this balancing act. Scientists, practitioners, industry, and ultimately all of us as citizens come together to direct data and methods in such a way that, in the best case, they can support courses of action, decisions on urban development.

Unlike planned, the next JURSE conference will not take place in May 2021 but in February 2022 in Medellin, Colombia—if the pandemic allows it (https://www.eafit.edu.co/jurse2021). The city of Medellin is considered a model city. Once notorious as the most dangerous city in the world in the 1990s, it transformed into a vibrant, cosmopolitan metropolis. And yet, the contradictions of global urban life are as visible as a magnifying glass: economically strong companies, well-known universities alongside extreme poverty and informal settlement development. The location is more than suitable for the next venue: it reflects what the JURSE is all about. High-tech developments in image analysis, information systems, and urban geography form a scientific perspective in conjunction with the everyday challenges of the city for decision-makers, industry and citizens.

This Special Issue showcases exemplary works on the diverse methodological and content aspects of remote sensing, heterogeneous datasets, and the processes of urbanization. It is precisely at the interfaces that we need to make connections in order to meaningfully translate data-driven approaches into social design possibilities. Let us meet in Medellin in 2022 for this discourse; let us continue to do so as members of these research and application fields open for a better city.

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ACKNOWLEDGMENT

The editors would like to thank the authors for their contributions to the Special Issue. The editors are grateful to the reviewers who committed their valuable time and knowledge to ensure that they maintain the high quality of the journal. The editors also would like to thank Prof. Jenny Du for welcoming our Special Issue in IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING and continuously supporting us. Finally, their warmest thanks go to the organizing team and sponsors of JURSE 2019. They strongly participated in making this event a great success.

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Dr. Lefèvre was the Co-Chair of GEOBIA 2016 and JURSE 2019. He is an Associate Editor for the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, and an Editorial Board Member of *Remote Sensing* and *ISPRS International Journal of Geo-Information*.

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Dr. Kuffer is co-chairing an international network on deprivation area mapping IDEAMAPS (https://ideamapsnetwork.org), and is presently working on two research projects related to deprivation area mapping SLUMAP (http://slumap.ulb.be) and ACCOUNT (https://slummap.net).

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Dr. Mallet is the Program Chair of the 24th ISPRS Congress, Nice, France (2020 and 2021). He is the Editor-in-Chief of the *ISPRS Journal of Photogrammetry and Remote Sensing*.